DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE OUTRIGGER TELESCOPES PROJECT

VOLUME I

Mauna Kea Science Reserve, Island of Hawai‘i

National Aeronautics and Space Administration
Office of Space Science
Washington, DC

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PREFACE

Rising 4,205 meters (13,796 feet) above sea level, the volcanic mountain Mauna Kea is the highest peak in the Hawaiian Islands and, from its base on the floor of the Pacific Ocean, the highest mountain on earth. Its main mass is built up from flows of lava and deposits of ash; its summit and upper slopes are dotted with cinder cones from more recent fiery eruptions, the last of which occurred more than 2,000 years ago. To the northeast it descends steeply, reaching the ocean shore 27 kilometers (17 miles) from the summit; to the west it drops more gently to the upland Waimea plain. To the south, a high plateau built up of lava from numerous volcanic flows from both Mauna Kea and Mauna Loa forms a Saddle between the two towering volcanic peaks.

Snow often whitens the summit in winter, and the name Mauna Kea is often translated in English as White Mountain. In Native Hawaiian traditions, however, “Kea” is also the abbreviated form of Wākea, the great sky god who, together with Papa, the earth mother, and other gods and forces, created the Hawaiian Islands. The summit is the meeting point of Wākea and Papa. In this cultural context, the island of Hawaiʻi was the first-born offspring of this union, the eldest of the islands. Wākea and Papa also became the parents of the first Native Hawaiian man, Hāloa, the first ancestor of the Hawaiian people.

These beliefs about Mauna Kea make it a highly significant and spiritual place to the Hawaiian people. Some Hawaiians view Mauna Kea as a natural temple, one built by the gods, a landscape that embodies their cultural values and links them to nature and the spiritual world. The ascent up the mountain takes one through various zones or levels of increasing sacredness and proximity to the spiritual beings of great power and importance (*akua*).

Hawaiian Traditions and Place Names. Polynesians sailing from islands to the south, in east central Polynesia, may have arrived in the Hawaiian Islands as early as 1,600 years ago and had certainly reached the islands and created permanent settlements by 1,200 years ago. They kept no written records, but they maintained a rich oral tradition of legends of gods and demigods, stories of their early ancestors, carefully maintained genealogies, and histories of the important chiefs who ruled in the islands. Both Native Hawaiians and foreign visitors and settlers recorded many of these traditions in the early years after Western contact in 1778. These provide a valuable source of information on traditional Hawaiian beliefs and practices concerning Mauna Kea.

As mentioned above, the name of Mauna Kea is probably associated with the god Wākea, whose son became the ancestor of all Hawaiian people. The cinder cone peaks of the mountain are named for ancient ancestors, many of whom are regarded as gods and goddesses; prominent among these are Kūkahauʻula, the pink-tinted snow god, Poliʻahu, goddess of the snows of Mauna Kea, and Līlīnoe, the goddess of mists. Other place names are descriptive or document events that occurred on the mountain. This application of meaningful place names to landscapes and natural features within landscapes helps shape the way in which a traditional culture conceptualizes these landscapes, linking places with significant deities, stories, or past events and acting to unite culture and nature.

Mauna Kea’s highest summit is Puʻu Kūkahauʻula, the traditional name for what is now often called Puʻu Wēkiu or Mauna Kea peak. Alternatively, Kūkahauʻula may include all the peaks in the summit cluster, encompassing all three of the highest volcanic cones, Puʻu Wēkiu, Puʻu Kea, and Pu‘u Hau‘oki. Kūkahau‘ula (Kū of the red-hewed dew or snow) is a form of the god Kū, but the peak is also said to be named for a chief of Waimea in South Kohala, who became the husband of Līlīnoe. Līlīnoe was a chieftess, who became the woman of the mountains, the goddess of mists. They were ancestors of Pae, who was a high chief in the time of ‘Umi (ca. the 16th century) and a *kahuna* known as an exceptional fisherman. When Līlīnoe died, she is said to have been buried on Mauna Kea; in 1828, Queen Ka‘ahumanu visited the mountain to try to recover the bones. The high peak southeast of Kūkahau‘ula bears the name Pu‘u Līlīnoe.

Kūkahau‘ula, the pink-tinted snow god, was also the lover of Līlīnoe’s sister Poli‘ahu. Poli‘ahu, after whom the high peak west of Pu‘u Kūkahau‘ula was named, became the goddess of the snows of Mauna Kea. She was not only the sister of Līlīnoe, but the rival of Pele, the volcano fire goddess, who lives at Kīlauea.

Two other names for places on Mauna Kea with particular importance in Hawaiian history and legend are Waiau and Kaluakākoi. Lake Waiau and Pu‘u Waiau are named for one of the god companions of Poli‘ahu. The lake is also sometimes called Poli‘ahu’s pond or spring. Kaluakākoi (cave or pit for making adzes), also called Keanakako‘i, is one of the main special-purpose areas near the summit, the Mauna Kea Adze Quarry.

Traditional Land Units. Native Hawaiians divided the island landscapes in which they lived both “vertically” (in units running from the mountain or mountain ridge summits to the ocean) and “horizontally” (in zones that correspond with altitude, vegetation pattern, and the types of resources available). The largest vertical divisions are the *‘āpana* or *moku* (district); the island of Hawai‘i is traditionally divided into six districts, Kohala, Kona, Ka‘ū, Puna, Hilo, and Hāmākua. The *‘āpana* or *moku* were in turn divided into *ahupua‘a*, the basic territorial unit under the control of a chief in the traditional Hawaiian political and social system. Each *ahupua‘a* generally stretched in a narrow band from the mountain tops to the coastal fishing grounds, giving residents access to a diversity of resources.

The summit region and western slopes of Mauna Kea are located within Hāmākua, a district that lies along the northeast side of Hawai‘i island. The summit lands of Mauna Kea, most lands on the upper slopes, its western slopes, and Saddle lands between Mauna Kea and Mauna Loa fall within Ka‘ohe *ahupua‘a* – a very large, inland, vertical land division within Hāmākua. Humu‘ula, the *ahupua‘a* southeast of Ka‘ohe, lies within Hilo district and covers lands on the lower slopes on the Hilo side of Mauna Kea, continuing beside Ka‘ohe across the Saddle to the summit of Mauna Loa.

Hawai‘i’s lands were also traditionally defined horizontally, as environmental and cultural zones, *wao*, defined largely by altitude, physical features, and vegetation. Six main zones are found on the slopes of Mauna Kea. *Kuahiwi* is the very sacred summit reserved as the realm of deities and high chiefs and priests. *Kualono* consists of the near-summit lands where few trees grow; this also is a very special zone. Downslope are four less sacred zones: *wao ma‘u kele* (below *kualono*; a wet area of large *koa*, *‘ōhi‘a*, lobelia, and *māmane)*; *wao akua* (an area of more varied forest–the name connotes the region of the gods – where cloud cover settles upon the mountain slopes); *wao kanaka* (the lowest forested area, dominated by *māmane* and *naio*, the zone most used as a cultural resource); and *kula* (the upland grassy plains). Only *wao kanaka* and *kula* were used for everyday purposes by Hawaiians; the two higher forest zones were special and their resources conserved.

Mountain Resources and Traditional Land Use. Early Polynesian settlers established themselves at coastal locations that provided easy access to ocean resources and to land well-suited for growing taro (the main Hawaiian staple food) and other crops. The first evidence for use of the high inland areas of Hawaiʻi island dates from the 12th or early 13th century. At this time Hawaiians began using the Saddle and the lower slopes of Mauna Loa to capture birds in the *māmane* and *naio* forests and to obtain basalt and volcanic glass for manufacturing tools. They sheltered overnight in the lava tube caves and blisters of the Pōhakuloa area.

At this same time, some journeyed up the slopes of Mauna Kea, camping in the shelter of overhanging rocks near the summit. The purposes of these early travelers are uncertain; most likely they made the arduous journeys for spiritual reasons to honor their ancestors and spirits associated with the mountains or perhaps even to make astronomical observations. On the summit plateau, they built shrines, each comprised of a single upright stone or of multiple upright stones set together in a row or rows or grouped within a paved court area. Unfortunately, in the absence of any organic remains associated with the summit shrines, it has not been possible to date directly the time of their construction and use.

The type of shrine built on Mauna Kea suggests that their construction dates quite early in Hawaiian prehistory. The use of uprights as the central focus of the shrines is similar to early *marae* (temples) common in the islands of central and eastern Polynesia, the area from which the Polynesian voyagers came to Hawaiʻi. Later, religious structures focused on uprights were replaced with a new type of temple structure as the Hawaiian *heiau* developed.

Although historical documents record the presence of an *ahu* or *heiau* at the summit, no shrines are now found on the central summit cones or in their immediate vicinity. Most are located on the summit plateau between 3,901 and 4,023 meters (12,800 and 13,200 feet) in elevation and are concentrated most heavily on the north and northeast side of the mountain. The absence of shrines within the core summit region suggests that this area was largely avoided because of its high degree of sacredness.

The upper, sacred zones were also used for burials; there is one cairn site on a cinder cone that has been confirmed as containing burials and four others are considered likely to contain burials. Other shrines, including those for bird-snarers and adze makers, were built on the mountain. Hawaiian traditions mention a possible *heiau* at Puʻu Līlīnoe, Pōhaku a Kāne, a sacred platform or *ahu* perched above the sacred water of Kāne; and an *ahu* or mound at Waiau. *Mele* (chants) were sung in special places within gulches including Kahawai Koikapue, whose waters were shared by Kaʻohe and Humuʻula.

The forested slopes of Mauna Kea from the Saddle up to the sacred zone above the forest were primarily an area into which Hawaiians came in search of specific resources or for specific purposes. Hawaiians collected colorful feathers from native honeycreepers, including the *ʻōʻō* in the lower forests on the mountain and in the Saddle. They also captured seabirds, especially *ʻuaʻu*, the dark-rumped petrel, that nested in the Saddle; the nestling chicks were prized as a special delicacy reserved for the chiefs. Oval cooking stones were heated and inserted into the body cavity of the birds to cook them; these stones are found at sites throughout the Saddle region. The Hawaiian duck (*kōloa*) and goose (*nēnē*) were hunted in the Saddle area, on the lower slopes (again, in *wao kanaka*), and possibly at higher elevations.

Hardwoods harvested from the forests included *koa* for canoe hulls and *'ōhi'a*. The very durable wood of *māmane* was valued for *'ō'ō* (spades, digging sticks) and the runners on sleds. *Pili* grass, along with bananas and *hāpu'u* (tree fern), were collected on lower slopes. Volcanic glass was gathered and fashioned into very fine cutting knives

Trails and footpaths served the lower slopes and also provided access to lower and upper forest zones on the mountain. The trail of Poli'ahu was an ancient trail, used by the powerful chief 'Umi in the 16th century; it passed by Waiau (Poli'ahu's spring) and the adze quarry near the Mauna Kea summit, providing a route from Kohala, Waimea, and west Hāmākua to Hilo. The trail of 'Umi passed around the east flank of the summit into the *koa* forests, providing the access for harvesting *koa*. This trail is also associated with important battles among chiefdoms when 'Umi united the islands. Other trails link the 'Umi trails and radiate to Hilo, Kona, and Waimea, as well as Hāmākua on the north flank of Mauna Kea.

Kaluakāko'i, the Mauna Kea Adze Quarry. As Hawaiians made their journeys to the summit, they discovered on the south side of the mountain, above the forest near the summit, in the second highest zone, large deposits of a very hard, fine-grained volcanic rock, a stone of much higher quality for making tools than any found elsewhere in the islands. Geologists interpret the origin of this stone as a result of unusual conditions, lava eruptions beneath the glacial ice that capped the summit during the Pleistocene, causing the magma to cool exceptionally quickly. This quick-cooled lava yielded an especially fine-grained stone that could be turned into high-quality adzes, the Hawaiian's primary tool for woodworking and canoe-making.

One such eruption from the Pu'u Waiau cinder cone formed an escarpment of dense rock that became the focus of stone procurement and working. For nearly 700 years, continuing until the beginning of Western contact, craftsmen skilled in stone-working journeyed up the mountain to quarry stone from the face of this escarpment below Lake Waiau. Archaeologists have identified over 264 workshops, mostly in a 4-sq-km area between 3,350 and 3,780 meters (11,000 and 12,400 feet) in elevation. These include areas where the stone was obtained and initially processed into blocks that could be taken elsewhere. Others are places where these blocks were further refined by percussion chipping. Some of these workshops include huge piles of waste debitage over 5 meters (16 feet) high where the raw material was processed into "preforms" that could serve as blanks for making adzes.

When staying on the cold summit, the workers found protection from the elements in the small rockshelters on the mountain slopes. In these shelters they left evidence of the foods carried to the summit, hearths for cooking the food and for warmth, and stone flaking debitage from tool manufacture. Their diet included sea urchins, barnacles, *'ōpihi*, several kinds of fish, birds (mostly dark-rumped petrel, but also including small numbers of native birds that are now rare or extinct, such as the Hawaiian rail, coot, goose, duck, crow, and honeycreepers), pig, dog, and Pacific rat. Taro was one of the most important foods, but ti, sugar cane, and gourd were also carried up from cultivated fields near the coast; seeds and fruits of wild plants were collected on the lower slopes of the mountain.

Also found in the rockshelters were tools and other indications of habitation. The entrances of many shelters were enclosed by rock walls. *'Ōpihi* shells may have been used as peelers for removing the corm or underground stem of the taro. Bird bone awls and volcanic glass flakes, used respectively to pierce and scrape wood and other soft materials, were other common tools. Normally perishable materials recovered in the shelters include a possible ti-leaf rain cape, sandal fragments, pandanus leaves, twisted cordage, and braided sennit. A silversword was wrapped with pieces of tapa cloth, pandanus leaf, and a wooden bottle gourd stopper with sennit cord attached.

An important aspect of the quarrying was the construction of shrines. As many as 45 shrines, identified by the presence of one or more upright stones, are found within the quarry. Most of these are directly associated with stone workshops or are above rockshelters, and their construction is therefore interpreted as relating to quarry activities. The surfaces of many shrines mimic workshops, with adze-manufacturing by-products scattered beneath the uprights, suggesting their use as ritual offerings. The quarry shrines clearly reflect the close integration of spiritual beliefs and material practices in traditional Hawaiian culture.

Post-Contact Land Uses and Environmental Change. Contact with the Western world, beginning with the arrival of Captain James Cook in 1778, altered in significant ways the relationship of the Native Hawaiians with Mauna Kea. The effect that appears to have been felt first after Contact was the reduction of the demand for stone tools with the introduction and then rapid and widespread adoption by the Hawaiians of iron tools. As a result, the need for new lithic raw material disappeared and quarrying activities on the Mauna Kea summit appear to have ceased very soon after Contact. No remains of tools, plants, or animals introduced by Cook or later voyagers are found in sites at the Mauna Kea Adze Quarry complex. Early European visitors to Mauna Kea, such as Joseph Goodrich in 1823, observed the piles of flakes and adze preforms and the shelters, but they say nothing about Hawaiian stone procurement or tool manufacture.

Several other factors reduced significantly the presence of Hawaiians on the mountain after Contact. Western apparel and paraphernalia replaced the traditional symbols of rank, such as the wearing of feathered cloaks and helmets, thus reducing the demand for colorful feathered birds from the upland forests. The introduction of foreign diseases to which the Hawaiians had no developed immunity severely reduced the population. The abolition of the *kapu* system in 1819 and the coming of Christian missionaries the next year meant that certain traditional ritual practices were discouraged. Those who continued to follow the traditions did so less conspicuously. Even though old shrines may have continued in use, new shrines were probably no longer erected on the mountain. While the traditional practices associated with the mountain were certainly not completely abandoned, as might be thought from reading 19^{th}-century documents of those foreign visitors who traveled around or up the mountain, they were not as prevalent as in pre-Contact times.

Widespread environmental change began on the slopes of Mauna Kea soon after the introduction of cattle and sheep in 1793 by the English explorer Captain George Vancouver, who brought them as a gift to Kamehameha I. Kamehameha banned killing of cattle and sheep for 10 years, and cattle soon began grazing over wide areas that included the slopes of the mountain. By the 1820s, the hunting of wild cattle became commercial, first supplying meat to the whaling ships and later tallow and hides for distant markets. Wild cattle, sheep, and goats soon destroyed much of the vegetation cover on slopes where they grazed, turning native forests, shrub lands, and grasslands into pasturelands covered by introduced grasses. Wild pigs spread invasive introduced plants, harming the forest understory and the native forest birds who had formerly fed in it. Pigs would also have fed on tree ferns, as they do elsewhere, encouraging water to pool in the stumps and inviting mosquitoes to breed. In the first half of the 19th century, the native *nēnē* was nearly hunted to extinction in the Saddle area.

Commercial harvesting of firewood and other lumber decimated *koa* forests on Mauna Kea and elsewhere. Sugar mills, in need of large amounts of firewood, depleted the mountain forests; their flumes both diverted mountain water and transported forest lumber downslope. *Pulu*, a silky fiber collected from *hāpu'u,* the tree fern, was collected for export as pillow and mattress stuffing.

In the 1830s cattle hunter John Parker established the beginnings of the ranch that would eventually cover the western half of the mountain. At mid-century, a sheep operation was established informally to take advantage of feral sheep already present in the Saddle. These two large ranches competed for the rights to raise cattle and sheep and hunt feral animals in the Saddle and on the lower slopes of the mountain. A wagon road was built from the sheep station at Humu'ula to Waimea to transport wool to the harbor at Kawaihae. Parker Ranch leased western Ka'ohe, while in 1885 the Humu'ula Sheep Station Company obtained the lease for the east side. The sheep station hired immigrant Japanese stonemasons to build stone walls around their grazing lands in the 1890s; portions of these are still standing. After 1900, Parker Ranch expanded and took over control of the Humu'ula Sheep Station Company, and most of the lands in the Saddle became a part of Parker Ranch.

In the late 19th century, the main trails on Mauna Kea increasingly merged with the wagon trails serving the Humu'ula Sheep Station and Umikoa Ranch, providing easier access to all the traditional *wao* (environmental zones), and to the summit. By 1890, grass had replaced forest on much of the slopes; the *māmane* forests had all but disappeared on the western side of the mountain; even the high mountain *'ahinahina* (silversword) had nearly vanished. The stripping of tree and shrub cover must have led to increasing erosion on all slopes in the uppermost zones and in deforested areas below.

Nineteenth-Century Visits to the Mountain. Early European and American visitors reported difficulty obtaining guides to the highest areas on Mauna Kea. Although the reason was almost certainly the sacredness and special status of the mountain in Hawaiian culture, especially the uppermost zones, some visitors concluded that the interior area was a virtually unknown wilderness. Foreign visitors apparently began to climb the mountain soon after Contact, as Goodrich and Ellis in 1823 found a rock cairn at the summit, probably left by an even earlier visitor.

Visits to the mountain increased in both frequency and in the numbers of people involved throughout the 19th century. In 1830, Kamehameha III, in the company of missionary Hiram Bingham, visited the mountain on horseback, their journey taking 5 days. In 1840, the Wilkes party (the U.S. Exploring Expedition party) documented Lake Waiau, and in 1862 Wiltse and others began surveying boundaries on the mountain for the Boundary Commission. Later, government surveyor J. S. Emerson sketched Mauna Kea. In 1883, Queen Emma traveled over the mountain to Waimea; a pillar or cairn built to commemorate her visit was observed in 1892 by W.D. Alexander. Surveyor E. D. Baldwin mapped the summit and near-summit areas, preparing a map in 1891. The Wilkes, Baldwin, and Alexander parties all erected cairns on the summit. The journals of these foreigners describe the wild cattle and the contrasts from tropical forest to grass and parkland to the severe starkness of the summit.

Recent Developments. The early 20th century brought additional change, with the planting by foresters of imported trees and other plants and early road construction. Sheep – some 40,000 around the mountain – were still numerous on the slopes in the 1930s. L. W. Bryan, head of the Civilian Conservation Corps (CCC) built a 97 kilometer (60-mile) long sheep-proof fence around the mountain to protect the remaining *māmane* forest and silversword, which had been devastated by wild sheep. Bryan directed the reforestation of denuded lands, planting large numbers of trees – most of them introduced species – to control erosion. The reforestation undoubtedly prevented much soil erosion, but also resulted in the additional isolation of the remaining patches of native forest.

The CCC improved roads, so that vehicles could now circumnavigate the mountain, the first step toward making the mountain more accessible. During World War II, the U.S. Army took control of a large area in the western portion of the Saddle that would become the Pōhakuloa Training Area. Military needs led to the construction of a graded, all-weather road through the Saddle by the CCC and U.S. Army Corps of Engineers in 1943. After the war, the Saddle Road, linking Hilo with Waimea, was paved, further easing access to Mauna Kea.

In the early 1960s, interest grew in using the summit for astronomical observations. In 1964, a road was cut to the summit, and four years later the Air Force 0.6-meter (24-inch) optical telescope was erected south of the summit ridge. In subsequent years, the existing twelve observatories were installed in the summit region, including the Keck, Subaru, and Gemini Telescopes in the central summit cone region.

Increased access to the mountain and the need to evaluate the consequences of the development of the observatories has led to a number of cultural resource and environmental studies during the past 30 years. This research has included an intensive archaeological study of the Mauna Kea Adze Quarry, cultural resource surveys that have recorded many of the shrines, and the biological discovery and study of the rare Wēkiu bug.

Today Mauna Kea is among the premier sites in the world for the study of the universe. Telescopes on Mauna Kea have been used to study disks of gas and dust surrounding young stars—nurseries of potential worlds—and to discern evidence for giant planets orbiting nearby stars. The Outrigger Telescopes Project would continue this record of discovery. As documented in this Environmental Impact Statement, the Project has been planned to minimize disturbance to the cultural and environmental resources of the mountain. The knowledge that the Outrigger Telescopes would provide would increase human understanding of the universe in the tradition of the great Hawaiian navigators.

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DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE OUTRIGGER TELESCOPES PROJECT

ABSTRACT

Lead Agency: National Aeronautics and Space Administration (NASA), Office of Space Science

Proposed Action: NASA's Proposed Action is to fund the on-site construction, installation, and operation of four, and possibly up to six, Outrigger Telescopes near the twin Keck Telescopes at the W.M. Keck Observatory site within the Mauna Kea Science Reserve on the island of Hawai'i. It is anticipated that the on-site construction and installation of four of the six Outrigger Telescopes, along with on-site construction of the underground structures for Outrigger Telescopes 5 and 6, would begin in 2005, with start of operations anticipated in 2007. If funding becomes available, NASA intends to complete the on-site construction, installation, and operation of Outrigger Telescopes 5 and 6, with above-ground construction and installation likely to begin no earlier than 2007.

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Abstract: NASA's Draft Environmental Impact Statement (EIS) for the Outrigger Telescopes Project addresses the environmental impacts associated with the Proposed Action and reasonable alternatives. The environmental impacts of principal concern for the Proposed Action are those that would affect cultural resources, the visual integrity of the summit region of Mauna Kea, and impacts to the Wēkiu bug, a candidate for listing under the Endangered Species Act. The environmental impacts of the Outrigger Telescopes Project on other environmental resource areas are also addressed as are the cumulative impacts of the Outrigger Telescopes when considered with past, present, and reasonably foreseeable future projects on or near Mauna Kea. NASA has also identified a reasonable alternative to the Mauna Kea site in Spain's Canary Islands. NASA's initial determination is that all of the science objectives set out for the Outrigger Telescopes Project can also be attained at this alternative site. This EIS addresses the environmental impacts associated with implementing the Outrigger Telescopes at the Canary Island site. The No-Action Alternative is also addressed. Should NASA decide not to fund the Outrigger Telescopes Project at either the proposed Mauna Kea site or at the alternative site in the Canary Islands, it may choose to implement a Reduced Science Option. The Reduced Science Option would consist of locating four Outrigger Telescopes at an existing observatory that does not have the large diameter telescope needed to achieve all of the science objectives possible with either the Proposed Action or the Canary Islands alternative site. Two Reduced Science Option sites have been identified. The environmental impacts associated with implementing the Reduced Science Option at each of the two sites in California are also addressed in this EIS.

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EXECUTIVE SUMMARY

This Draft Environmental Impact Statement (EIS) has been prepared in accordance with the National Environmental Policy Act of 1969, as amended (42 U.S.C. §4321 *et seq.*); the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR Parts 1500-1508); and the National Aeronautics and Space Administration's (NASA) policy and procedures (14 CFR Subpart 1216.3) to support decision-making on whether to fund the on-site construction, installation, and operation of the Outrigger Telescopes Project. No final action will be taken by NASA regarding funding for the on-site construction, installation, and operation of the Outrigger Telescopes until the decision-making process under the National Environmental Policy Act has been completed.

This Federal National Environmental Policy Act process is separate and distinct from the State environmental process completed by the University of Hawai‘i in accordance with applicable State of Hawai‘i environmental statutes and regulations.

ES.1 PURPOSE AND NEED

A detailed description of the purpose and need for the Outrigger Telescopes Project can be found in Chapter 1 of the EIS.

NASA has a central Mission with three components: (1) to understand and protect our home planet, (2) to explore the universe and search for life, and (3) to inspire the next generation of explorers. The second component, to explore the universe and search for life, addresses two of humanity's oldest and most profound questions: "Where did we come from?" and "Are we alone?" Understanding where we come from requires knowledge of how today's universe of galaxies, stars, and planets came to be, and how stars and planetary systems form and evolve. Understanding whether or not we are alone requires knowledge about the building blocks of life, the conditions necessary to sustain life, and the diversity of planets—particularly those that might harbor life. Acquiring knowledge in all of these areas is the goal of NASA's Origins Program. In pursuit of this knowledge, NASA supports space flight missions, related research programs, and technology development.

Interferometry is a critical technology for accomplishing the Origins Program. It is a technique for overcoming an inherent limitation of single telescopes: the "sharpness" or amount of image detail is limited by the size of the telescope's main mirror. An interferometer combines two or more telescopes optically so they function as if they were a single larger telescope. The number of individual telescopes and the distances between them determines the sharpness of the image from an interferometer. Because the separation between telescopes can be much larger than the diameter of even the largest telescope mirrors, interferometers in general acquire images that capture much more detail than individual telescopes.

Interferometers also can measure positions of stars with exquisite accuracy. This is important because it is possible to find planets around other stars by measuring the stars' positions very accurately over a substantial period of time. As a planet orbits a star, it exerts a gravitational tug that causes the star to move back and forth. An interferometer can detect this slight "wobble," thus revealing the presence of the orbiting planet.

NASA is developing interferometry for use both in space and on the ground. Space flight missions, such as the Space Interferometry Mission scheduled for launch in 2009, can achieve even finer measurements than are possible from the ground by getting above the Earth's atmosphere to avoid its image distortion. However, ground-based interferometers are essential for projects that require a longer operating life than is possible with a space flight mission. They can also involve telescopes that are larger and more sensitive than the ones that can be flown in space.

The Outrigger Telescopes Project is part of NASA's program to develop ground-based interferometry. The project as proposed addresses four of NASA's six scientific objectives for ground-based interferometry. These six objectives are:

1. Detect the thermal dust emissions from dust clouds around other stars.
2. Detect the light from and characterize the atmospheres of hot, Jupiter-mass planets located within approximately 20 million kilometers (km) (12 million miles (mi)) of the stars they are orbiting.
3. Detect the astrometric signature (*i.e.*, the wobble of a star due to the gravitational influence of an unseen planetary companion) of planets as small as Uranus.
4. Make images of proto-stellar disks (*i.e.*, disks of dust and gas in space believed to be an early stage of star formation) and stellar debris disks (*i.e.*, clouds of gas or other material remaining after the star is formed).
5. Provide high-resolution information about some faint objects outside our galaxy.
6. Make high-resolution observations of objects within the solar system, including asteroids, comets, and outer planets.

The first two objectives can be accomplished by the Keck-Keck Interferometer which links the two 10-m (33-ft) Keck Telescopes. Objectives 3 through 6 require the Outrigger Telescopes. Objective 3, finding planets around nearby stars by means of astrometry, can be accomplished with four Outrigger Telescopes alone. Objectives 4 through 6 require that the Outrigger Telescopes be connected to one or more large (8-meter (m) (26-foot (ft)) diameter or larger) telescopes. Six Outrigger Telescopes would provide almost twice as much image detail as four in pursuit of objectives 4 through 6, yielding much higher quality scientific data.

TERMS TO KNOW

Outrigger Telescope refers to any of the proposed 1.8-meter (6-foot) diameter telescopes.

Keck Telescope refers to one of the two 10-meter (33-foot) diameter telescope.

Keck-Keck Interferometer refers to the Keck I and Keck II Telescopes used together as an interferometer (without the Outrigger Telescopes).

Keck Interferometric Array refers to any combination of some or all of the Outrigger Telescopes with one or both of the Keck Telescopes.

ES.2 PROPOSED ACTION AND ALTERNATIVES

A detailed description of NASA's Proposed Action and reasonable alternatives can be found in Chapter 2 of this EIS.

NASA's Proposed Action is to fund on-site construction, installation, and operation of four, and possibly up to six, Outrigger Telescopes at the W.M. Keck Observatory site located within the Astronomy Precinct on the summit of Mauna Kea, island of Hawaii.

NASA also systematically evaluated ten other potential sites for locating the Outrigger Telescopes Project. Of the ten sites evaluated, one site emerged as a reasonable alternative to the Mauna Kea site. This site, located in Spain's Canary Islands, is called the Gran Telescopio Canarias (GTC) site. NASA's initial evaluation of this site indicates that all of the science objectives established for the Outrigger Telescopes Project could be achieved at this site as well as at Mauna Kea. The environmental impacts of funding on-site construction, installation, and operation of the Outrigger Telescopes Project at this alternative site are also addressed in this EIS.

The remaining alternative addressed in this EIS is the No-Action Alternative.

ES.2.1 Description of the Proposed Action

The W.M. Keck Observatory site on Mauna Kea is the location of the two most powerful optical telescopes in the world—Keck I and Keck II. The proposed Outrigger Telescopes would be placed strategically around the existing Keck Telescopes on the area of the cinder cone, Pu‘u Hau‘oki, that was previously disturbed for construction of the two Keck Telescopes. NASA anticipates that on-site construction and installation of four Outrigger Telescopes along with on-site construction of the underground structures for Outrigger Telescopes 5 and 6 would begin in 2005 (assuming all permits and approvals have been received) with start of operations anticipated in 2007. If funding becomes available, NASA intends to complete the above-ground construction, installation, and operation of Outrigger Telescopes 5 and 6, with on-site construction and installation likely to begin no earlier than 2007.

Each proposed Outrigger Telescope would consist of a 1.8-m (6-ft) diameter, f/1.5 primary mirror, a secondary mirror, a tertiary mirror, and other optical equipment. A dome, measuring 9.1 meters (30 feet) in diameter at its widest point and 8 meters (26 feet) in diameter at its base, would enclose each telescope to protect it from the harsh conditions on Mauna Kea. The domes would stand 10.7 meters (35-feet) high as measured from the top of the level grade at elevation 4,146 meters (13,603 feet). By comparison, each of the Keck domes is 37 meters (121 feet) in diameter at its widest point and 33.9-meters (111-feet) high. Each proposed Outrigger Telescope would be supported by an underground concrete telescope instrument room, which would serve as a telescope pier. Junction boxes would house the mirrors that direct the light beams through underground light pipes to the basement of the Keck II Telescope building, where the interferometer instrumentation is located.

ES.2.2 Environmental Impacts of the Proposed Action

ES.2.2.1 Cultural Resources

The Hawaii State Historic Preservation Division (SHPD) believes that Kūkahau‘ula, the area of the three summit cones of Mauna Kea, meets the criteria for listing in the National Register of Historic Places primarily because of its importance as a traditional cultural property. Some Native Hawaiians have identified the larger area of Mauna Kea, from the 1,829-m (6,000-ft) elevation to the summit, as a sacred landscape valued for its spiritual significance.

Pursuant to regulations under the National Historic Preservation Act (NHPA), NASA proceeded with the Section 106 process. Initially, NASA formally invited four Native Hawaiian organizations to act as Consulting Parties:

(1) Hui Mālama I Nā Kūpuna o Hawaiʻi Nei (this organization is referenced in the NHPA),

(2) Hawaiʻi Island Burial Council,

(3) OHA (also referenced in the NHPA), and

(4) The Royal Order of Kamehameha I.

The Advisory Council on Historic Preservation (ACHP) also agreed, at NASA's invitation, to participate in the Section 106 process. Two more Native Hawaiian organizations later requested and were given Consulting Party status: Ahahui Ku Mauna and Mauna Kea Anaina Hou.

NASA also consulted with and invited the Office of Mauna Kea Management (OMKM), the Mauna Kea Management Board, and Kahu Kū Mauna to participate in the development of mitigation measures under the Section 106 process.

As part of the Section 106 consultation process, NASA prepared proposals for on-site and off-site mitigation of potential impacts to cultural resources for consideration by the SHPD, ACHP, and the other Consulting Parties. These proposals subsequently led to a Memorandum of Agreement (MOA) which stipulates mitigation measures.

Signatories to the MOA included NASA, the Advisory Council on Historic Preservation, the Hawaiʻi State Historic Preservation Officer, UH, the California Association for Astronomy (CARA), the California Institute for Technology (Caltech), and Ahahui Ku Mauna (with caveat). Consulting Parties who did not sign the MOA included the Hawaii Island Burial Council, Hui Mālama I Nā Kūpuna o Hawaiʻi Nei, Mauna Kea Anaina Hou, the Office of Hawaiian Affairs, and The Royal Order of Kamehameha I.

No archaeological sites have been identified in the area of the Proposed Action. However, there are archaeological sites and historical architectural resources in the vicinity of the staging area at Hale Pōhaku. These are extremely unlikely to be adversely affected by the Proposed Action.

In addition, no area at or near the summit is assumed to be devoid of archaeological resources. NASA has therefore proposed mitigation measures that assume that archaeological resources could be found anywhere during on-site construction. A Draft Burial Treatment Plan has been prepared that stipulates procedures to be followed if burial remains are found.

If an archaeological resource is discovered during excavation for the Outrigger Telescopes, the mitigation measures as described in the MOA will prevent or reduce adverse effects.

The Outrigger Telescopes Project would have an small adverse effect on traditional cultural properties and practices in the summit region. The primary impact would be the continued visual presence of the telescope structures within the Kūkahauʻula traditional cultural property. However, because the Outrigger Telescopes would be located next to the much larger Keck I and II structures, their impact would be a small increment to the impact that has already occurred. The Outrigger Telescopes Project would not in any way restrict access of Native Hawaiians to the summit region.

ES.2.2.2 Biological Resources and Threatened and Endangered Species

The major focus of potential biological impacts of the Outrigger Telescopes Project is the Wēkiu bug. The Wēkiu bug (*Nysius wekiuicola)* is a candidate for listing under the Endangered Species Act of 1973. The proposed Outrigger Telescopes Project would displace a small amount of previously disturbed Wēkiu bug habitat (0.008 hectare (0.019 acre)). A Wēkiu Bug Mitigation Plan has therefore been developed to reduce or avoid adverse impacts. This plan includes habitat restoration to replace the displaced habitat in a restoration ratio of at least 3:1. The habitat restoration portion of the plan was developed in conjunction with the U.S. Fish and Wildlife Service (USFWS) and other scientists familiar with Wēkiu bug ecology. A qualified entomologist would be on-site monthly to monitor implementation of the proposed mitigation measures and measure the effectiveness of habitat protection and restoration efforts.

When the Wēkiu Bug Mitigation Plan and the Wēkiu Bug Monitoring Plan are implemented, the anticipated adverse impacts to the biological resources as a result of the Outrigger Telescopes Project would be small. Through restoration, the amount of Wēkiu bug habitat adjacent to the W.M. Keck Observatory would increase. The Outrigger Telescopes Project would have no significant impacts on the biological resources within the ROI.

ES.2.2.3 Hydrology, Water Quality, and Wastewater

Three principal activities could potentially have impact on water quality during construction: (1) the process of washing cinder for Wēkiu bug habitat restoration in Submillimeter Valley directly south of Puʻu Hauʻoki, (2) using water to control dust, and (3) accommodating the water supply and wastewater treatment and disposal needs of construction workers. Similarly, two aspects of the Outrigger Telescopes operations have potential hydrologic and/or water quality impacts: (1) change in surface runoff from the W.M. Keck Observatory site, and (2) generation and disposal of domestic wastewater.

An analysis under a very conservative set of assumptions shows that the Outrigger Telescopes Project would have no impact to hydrology and/or water quality. In particular, percolating wastewater from the W.M. Keck Observatory site would not travel to Lake Waiau or to the springs on the west side of Pōhakuloa Gulch.

ES.2.2.4 Solid Waste and Hazardous Materials Management

On-site construction activity associated with the Outrigger Telescopes Project would generate waste debris consisting of wood, scrap insulation, packaging material, waste concrete, and various construction-related wastes. On-site construction and installation contract(s) would contain provisions regarding the management of these wastes. Particularly important are measures to secure solid wastes against dispersal by high winds. Given appropriate precautions, no impacts from solid wastes are anticipated.

No mercury would be used for the Outrigger Telescopes. The rinse water from the mirror recoating process would be collected and transported off the mountain.

Some hazardous materials, such as paints, thinners, solvents, and fuel, would be used for the Outrigger Telescopes Project. Unused products and spent containers would be collected and transported offsite for proper disposal. Handling of these materials would be guided by best management practices. With these measures in place, no impacts from hazardous materials handling are anticipated.

ES.2.2.5 Geology, Soils, and Slope Stability

There would be only small impacts to geology, soils, and slope stability during the construction phase of the Outrigger Telescopes Project. Because Outrigger Telescopes 3 and 4 are to be built close to the steep edges of Pu‘u Hau‘oki, retaining walls would be built at the upper edges of these slopes so that excavated cinders and debris do not cascade downslope during construction. This would also prevent foot traffic from degrading the slope edge following construction. All construction activities will be conducted in accordance with a Construction Best Management Practices Plan.

There would be no impacts during the operations phase of the Outrigger Telescopes.

ES.2.2.6 Land Use and Existing Activities

The Outrigger Telescopes Project would be consistent with uses permitted in the Astronomy Precinct of the Mauna Kea Science Reserve and with the 2000 MKSR Master Plan.

Although some transportation, noise, and visual impacts would occur, it is anticipated that the Outrigger Telescopes Project would not result in a long-term conflict with or have a substantial impact on existing activities. In particular, use of the land for cultural and religious practices, astronomical and other scientific research, and a variety of recreational activities would remain consistent with the current use.

ES.2.2.7 Transportation

Vehicular traffic would occasionally delay traffic along the Mauna Kea Access Road. The greatest traffic delays would occur when the telescopes and domes are trucked up the mountain. This traffic would occur only intermittently and thus should not regularly interfere with normal traffic flow. Construction vehicles would not have any long-term impact on either the road or overall traffic flow. The slight increase in traffic associated with operations would be insignificant.

ES.2.2.8 Utilities and Services

Although the Outrigger Telescopes Project would increase demand for potable water on Mauna Kea, there would be no impact to the existing water supply at the W.M. Keck Observatory site or at Hale Pōhaku.

There would be only a minor increase in electrical demand during construction and installation. The Hale Pōhaku power substation has capacity to accommodate the power requirements of all six Outrigger Telescopes.

The communications system for Mauna Kea has adequate capacity to accommodate the addition of the Outrigger Telescopes.

The impacts on emergency services and fire suppression would be small.

ES.2.2.9 Socioeconomics

The Outrigger Telescopes Project would have a small positive socioeconomic impact on the County and State of Hawai‘i.

ES.2.2.10 Air Quality

The Outrigger Telescopes Project would result in short, small, but measurable levels of air pollution during construction and installation. Strict compliance with the State Department of Health (DOH) Administrative Rules and the County of Hawai’i grading permit would minimize the short-term effects on air quality. Potable water will be applied to excavation sites and cinder stockpiles to minimize dust during trenching, bulldozing or other soil disturbance activities. In summary, there would be a small impact.

The operation of the Outrigger Telescopes would have no impact on air quality in and around Mauna Kea.

ES.2.2.11 Noise

Construction and installation activities would generate noise. Actual noise levels would depend upon the mix and duration of construction equipment and methods used. A noise level increase could affect cultural and religious practices. However, any noise disturbances or interruptions would end once on-site construction and installation is completed. It is anticipated that noise increases during construction and installation would be moderate.

Operation of the Outrigger Telescopes would result in a negligible increase in noise.

ES.2.2.12 Visual/Aesthetics

The Outrigger Telescopes would be visible from most locations within the Astronomy Precinct. However, they would not be visible from the true summit, and one or more Outriggers would generally be obscured by the Keck Telescope domes.

Below the summit area, the mountain topography would determine visual impacts from the Outrigger Telescopes. The Outriggers would generally be visible from off-mountain locations to the north and west of the summit such as Waimea and Honoka'a. They would not be visible from locations to the east and south such as Hilo and the Saddle Road. Where visible, the Outrigger Telescopes' visual impact would be small compared to the impact of the much larger Keck Telescope domes.

ES.2.2.13 Cumulative Impacts

The Council on Environmental Quality NEPA implementing regulations define cumulative impacts as the incremental environmental impacts of the action when added to other "past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." Cumulative impacts can result from individually minor, but collectively significant, actions taking place over time.

During the scoping process for this EIS, NASA consulted with interested agencies and the public who identified the following important cumulative impact concerns associated with the Outrigger Telescopes Project: the Wēkiu bug and its habitat on Mauna Kea; the release of sewage system effluents into subsurface cinder at the summit; and, even more importantly, the central role of Mauna Kea in the cultural and spiritual life of Native Hawaiians.

NASA also determined that, in general, the time frame for the cumulative impact evaluation would extend from about 1964, before the first telescope was installed on Mauna Kea until the year 2033 when the lease agreement between the State of Hawaii and UH ends. NASA consulted with the community, local organizations, government agencies, and the existing observatories on Mauna Kea to identify projects and activities on or near Mauna Kea that could occur within the reasonably foreseeable future, i.e., between the present and 2033.

Past activities considered in the cumulative impact analysis include all observatory construction and related activities. Foreseeable future activities include both astronomy and non-astronomy related projects and activities. Activities at the end of the lease agreement in 2033 have been addressed by considering two bounding possible outcomes.

Cultural Resources. Mauna Kea has a rich traditional history and many archaeological sites, including some that have yet to be discovered. Before 1982, only limited cultural and archaeological surveys were conducted in preparation for developments on the mountain. Thus, it is not known whether development of the Astronomy Precinct beginning in 1964 has damaged subsurface cultural resources. However, such development has clearly altered the appearance of the Kūkahau‘ula traditional cultural property, interfered with views to and from the summit, and affected traditional cultural uses and practices. Grading and removal of earth for new structures, redeveloped structures, roads, and other astronomy projects could further affect these resources adversely. Following appropriate mitigation measures, such as those described in the NHPA Section 106 MOA, and developing project-specific mitigation measures for future activities would reduce adverse effects.

Mitigation measures developed for the Outrigger Telescopes Project and made part of the Section 106 MOA would minimize the impact of the Outrigger Telescopes Project and could potentially provide beneficial impacts, including community outreach and cultural stewardship.

From a cumulative perspective, the impact to cultural resources on Mauna Kea is substantial and adverse. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have a small incremental impact.

Biological Resources and Threatened and Endangered Species. There have been substantial impacts to biological resources, particularly the Wēkiu bug, a candidate species for listing under the Endangered Species Act, but the best available information does not always permit complete understanding of the causes of those impacts. The impact of reasonably foreseeable future activities is likely to be moderate to substantial. The incremental impact of the Outrigger Telescopes Project is small and not significant. Further, on balance, the Project’s impact is likely to be beneficial to biological resources. Overall, the cumulative impact to biological resources is adverse and significant.

Hydrology, Water Quality, and Wastewater. The impact of all past, present, and reasonably foreseeable future astronomy related projects, including the Outrigger Telescopes Project, on the hydrologic system is virtually zero. Therefore, the cumulative impact on hydrology and water quality is not significant.

Solid Waste and Hazardous Materials Management. Impacts of solid waste on biological or hydrological resources or aesthetics from past, present, and reasonably foreseeable activities have been small, if any, transient, and not significant. The incremental impact of the Outrigger Telescopes Project would be small and not significant.

Impacts of hazardous materials on biological and hydrological resources and aesthetics from past, present, and reasonably foreseeable activities have been small and not significant. The incremental impact of the Outrigger Telescopes Project would be small and not significant.

Geology, Soils, and Slope Stability. The impact of past and present activities on geology, soils, and slope stability has been substantial. The impact of foreseeable future activities is anticipated to be small. The Outrigger telescopes would add a small and not significant incremental impact. The overall cumulative impact has been significant.

Land Use and Existing Activities. Most past, present, and reasonably foreseeable future activities on Mauna Kea have been consistent with State and local plans and compatible with State land use designations. The Outrigger Telescopes Project would have no incremental impact on land use.

From a cumulative perspective, the impacts of past, present, and reasonably foreseeable future activities on existing activities on Mauna Kea are substantial. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have a small incremental impact.

Transportation. Past, present, and reasonably foreseeable future activities result in greater access for visitors and Native Hawaiians traveling to Mauna Kea. As a result, there has been a substantial increase in traffic volume along the access road. This increase has resulted in a substantial impact on the natural setting of Mauna Kea.

The on-site construction and installation of the Outrigger Telescopes would result in a small, short-term increase in the current traffic volume. Operations of the Outrigger Telescopes would contribute only a small increase in current traffic levels. From a cumulative perspective, the transportation impact on Mauna Kea has been significant. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have a small incremental impact.

Utilities and Services. Past, present, and reasonably foreseeable future activities on Mauna Kea have led to the development of a water supply system, which constitutes a substantial impact on water supply. The water usage and traffic associated with water delivery are small and not significant in comparison to overall island water usage and Mauna Kea traffic levels. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have almost no incremental impact.

Past and present activities on Mauna Kea have led to the development of electrical power and communications infrastructure, which constitutes a substantial impact on such capability. Reasonably foreseeable future activities are anticipated to have a small additional impact on electrical power and communications. The Outrigger Telescopes Project would have no incremental impact on the existing electrical distribution and communications systems.

Past and present activities on Mauna Kea have led to the development of emergency services and fire suppression capability. It is anticipated that foreseeable future activities would require similar additional development. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have no incremental impact.

Socioeconomics. The impact of past, present, and reasonably foreseeable future activities within the Astronomy Precinct on socioeconomics is substantially positive. The Outrigger Telescopes Project would add a small positive incremental impact. The overall cumulative impact on socioeconomics is substantial and positive.

Air Quality. Past and present activities have had a minor continuing impact on air quality. Foreseeable future activities would have similar impacts. The Outrigger Telescopes Project would employ mitigation measures and would have a very small incremental impact. Overall, the cumulative impacts to air quality are small.

Noise. The impact of noise from past, present, and reasonably foreseeable future activities is generally small. The Outrigger Telescopes Project would have almost no incremental impact. Although individual construction events would continue to produce occasional increased noise levels, overall noise conditions in the ROI would remain low.

Visual/Aesthetics. The visual impacts of past and present astronomy-related activities in the MKSR have been substantial. Future visual impacts may be minimized by new design guidelines and careful site selection of new development projects. Mitigating dust generation, enforcing strict trash control, and minimizing on-site staging areas would reduce local short-term visual impacts. The Outrigger Telescopes Project would add a small incremental visual impact. Overall, the cumulative visual impact from past, present, and reasonably foreseeable activities is substantial.

Cumulative Impact Summary. In conclusion, the overall cumulative impact of past, present, and reasonably foreseeable activities is substantial, adverse, and significant. In general, the Outrigger Telescopes Project would add a small incremental impact.

ES.2.3 Description of the Gran Telescopio de Canarias (GTC) Alternative

The Gran Telescopio de Canarias, a 10-m (33-ft) telescope modeled after the Keck Telescope, is currently under construction on the island of La Palma in Spain's Canary Islands, about 1,800-km (1,100-mi) southwest of Madrid, Spain. The GTC site is located within the Roque de Los Muchachos Observatory near the northern end of the island.

The Roque de Los Muchachos Observatory is located at an elevation of approximately 2,400 m (7,900 ft) above mean sea level and occupies the north slope of a large volcanic caldera, the most prominent feature on La Palma. The 189-ha (467-ac) science site supports more than a dozen observatories. The GTC site may be characterized as a broad northwest sloping (18 percent) plain of altered volcanic material. A sizeable area adjacent to the GTC site has been disturbed by material staging and construction activities, but other adjacent area is undisturbed.

Locating the Outrigger Telescopes Project at the GTC site would involve the construction of four, and possibly up to six, 1.8-m (6-ft) Outrigger Telescopes together with their enclosures and domes, light pipes to transport the light from each telescope to a central beam combiner, and a separate structure to house the beam combiner facility. The GTC is being constructed with a coudé tunnel beneath the building which allows light from the 10-m (33-ft) telescope to be brought outside the observatory structure. This light path would feed directly into the beam combiner facility. The light pipes relaying light from the Outrigger Telescopes would also feed into the beam combiner facility, where a complex system of optics would combine the light of the various telescopes together interferometrically.

ES.2.4 Environmental Impacts of the Canary Islands Alternative

ES.2.4.1 Cultural Resources

There are no groups that consider the ORM to be sacred or of religious importance, thus on-site construction and installation will have no impact on traditional cultural practices. Certain configurations of the Outrigger Telescopes could involve placing some of the Outrigger Telescopes in areas not previously surveyed for archeological properties. For that configuration, additional archeological surveys would be required. Based on prior experience, there is a reasonable likelihood that one or more additional archaeological sites would be discovered. However, suitable mitigation is likely to be possible.

Impacts to archaeological resources are likely to be small.

ES.2.4.2 Biological Resources and Threatened and Endangered Species

A sizeable area adjacent to the GTC has been disturbed by material staging and construction activities. The relative impact of the Outrigger Telescopes Project would depend on the location of these telescopes in relation to the GTC. While it may be feasible to locate the Outrigger Telescopes wholly in previously disturbed areas, from a science and research perspective the optimal configuration would likely be similar to that on Mauna Kea (the Outrigger Telescopes placed in a configuration surrounding the GTC). Such a configuration would involve siting of some telescopes in previously undisturbed areas, leading to destruction of flora. Because of the nature of the site and flora involved, there would be difficulty in flora reestablishing itself. However, the relatively small size of the Outrigger Telescopes would necessarily limit the area of disturbance.

Animals temporarily may leave the immediate vicinity during the period of construction and installation due to human presence and activity, and noise. Many of those species would return after on-site construction and installation are complete.

The 1999 environmental survey for the GTC resulted in a finding of no impact to protected species within the GTC site area. Since construction and installation activities associated with the Outrigger Telescopes would be similar to but smaller in scale than the GTC, no impact to any protected species is anticipated.

In summary, the impact on flora and fauna would be minor. Impacts to fauna would be temporary; it could take some period of time for flora to reestablish itself.

ES.2.4.3 Hydrology, Water Quality, and Wastewater

Water would be trucked to the site. The septic system and leach field at GTC have been approved by local authorities.

Some of the water applied for dust control would be lost to evaporation and the remainder would percolate downward. While the percolation process should be similar to that on Mauna Kea, a clay-like sub-layer in the soil at the GTC may result in some horizontal displacement of the percolating water. Minor hydrologic impact from dust control would be expected.

Outrigger Telescopes construction activities may affect precipitation run-off from the site, but impacts to hydrology and water quality would be small. No water channels or drainages cross the site. Implementation of a BMP would minimize alteration of drainage.

Potential impacts from operations of the Outrigger Telescopes at the GTC site are similar to those of the Proposed Action.

ES.2.4.4 Solid Waste and Hazardous Materials Management

The analysis of these impacts and mitigation measures (with the exception of Wēkiu bug mitigation measures) for the W.M. Keck Observatory site generally apply to the GTC site as well. With appropriate handling of hazardous materials, there would be no impact arising from such materials.

ES.2.4.5 Land Use and Existing Activities

Spanish law has designated astronomy activities as compatible with other traditional uses within the ORM. Thus on-site construction, installation, and operation of the Outrigger Telescopes would be compatible with and not adversely affect land use designation. Other than astronomy and a relatively small amount of tourism there are no existing activities of any note in the area of ORM. There would be no impact.

ES.2.4.6 Geology, Soils, and Slope Stability

The altered state due to weathering of the volcanic material in the upper soil layers results in a surface subject to erosion as a result of project related activities. Careful design would ensure that the Outrigger Telescopes are placed on stable foundations. Best management practices would include measures to minimize erosion. Such measures would likely need to be more extensive than at the W.M. Keck Observatory site. With available mitigation methods, the adverse impacts to soils and slope stability are anticipated to be small.

ES.2.4.7 Transportation

Since traffic can use two routes to the ORM and visitor activity is relatively low, there is likely to be much excess traffic capacity. Overall adverse transportation impact would be small and less than at Mauna Kea.

ES.2.4.8 Utilities and Services

Except for electrical power, the impacts on utilities and services are similar to those for the Proposed Action.

The electrical load of the Outrigger Telescopes combined with that of GTC would approach and perhaps exceed existing capacity. The situation would be even more problematic in the event of an emergency. Overall, the adverse impact to electric power supply would be substantial without upgrades. With such additional infrastructure, the adverse impact would be small.

ES.2.4.9 Socioeconomics

Excluding the need to add certain facilities at the GTC site that presently exist at the W.M. Keck Observatory (e.g., an interferometer and associated equipment, electric power upgrades, etc.), on-site construction, installation, and operations costs would be approximately the same. There would relatively be a greater socioeconomic benefit to La Palma and the Canary Islands than to the Island and State of Hawaiʻi because of the relative sizes of the local economies. Overall, Outrigger Telescopes Project would offer a moderate socioeconomic benefit to La Palma and small benefit to the Canary Islands.

ES.2.4.10 Air Quality

The two highway routes to the GTC are entirely paved. There would therefore be no dust generated by construction or operations traffic to and from the GTC. With the implementation of mitigation measures similar to those that would be employed for the Mauna Kea site the environmental impacts on air quality are expected to be small and slightly less than for the W.M. Keck Observatory site.

ES.2.4.11 Noise

The analysis for the W.M. Keck Observatory site generally applies to Outrigger Telescopes construction at the GTC site with the following exceptions: there are no religious practices conducted in the vicinity of the GTC site; there is little recreational use in the vicinity of the GTC site. Noise impacts from construction would be small and less than at Mauna Kea. Operation noise impacts would be effectively zero.

ES.2.4.12 Visual/Aesthetics

Approval of the GTC project by the National Park de la Caldera de Taburiente was dependent, in large part, upon the fact that it would not be visible from the south rim visual overlooks. The Outrigger Telescope enclosures would be much shorter than the GTC thus would not be visible from the south rim. The adverse impact would be effectively zero.

ES.2.5 Reduced Science Option

Should NASA decide not to fund the Outrigger Telescopes Project at either the Mauna Kea site as proposed, or at the alternative site in the Canary Islands, it may choose to implement a Reduced Science Option. The Reduced Science Option would consist of locating four Outrigger Telescopes at an existing observatory that does not have the large diameter telescope needed to achieve all of the science objectives that would be possible with either the Proposed Action or the Canary Islands alternative.

NASA identified two candidate sites for the Reduced Science Option that warranted detailed study. Both sites are in California: Mount Wilson and Palomar Mountain. Chapter 6 of the EIS contains detailed analyses of the environmental impacts of locating the Reduced Science Option at each of the two sites. While implementation of the Reduced Science Option at either candidate site would result in environmental impacts, the intensity of which would vary between the two sites, no significant environmental impacts would occur at either site.

ES.2.6 No-Action Alternative

Under the No-Action Alternative, NASA would not fund on-site construction, installation, or operations of the Outrigger Telescopes Project. NASA's purpose and need for the project would not be met.

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ACRONYMS AND ABBREVIATIONS

ac	acre
ACHP	Advisory Council on Historic Preservation
AU	astronomical unit
BLNR	Board of Land and Natural Resources
BMP	Best Management Practices Plan (construction)
Caltech	California Institute of Technology
CARA	California Association for Research in Astronomy
CARB	California Air Resources Board
CCR	California Code of Regulations
CDUA	Conservation District Use Application
CDUP	Conservation District Use Permit
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFHT	Canada-France-Hawaiʻi Telescope
CFR	Code of Federal Regulations
CHARA	Center for High Angular Resolution Astronomy
CIW	Carnegie Institution of Washington
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
CSO	Caltech Submillimeter Observatory
CZM	Coastal Zone Management
dBA	A-weighted decibel
DHHL	Department of Hawaiian Homelands
DLNR	Department of Land and Natural Resources (State of Hawaiʻi)
DOH	Department of Health (State of Hawaiʻi)
EA	Environmental Assessment
EHS	Extremely Hazardous Substance
EIS	Environmental Impact Statement
EMS	Emergency Medical Service
EMT	Emergency Medical Technician
EPCRA	Emergency Planning and Community Right-to-Know Act
FHWA	Federal Highway Administration
FONSI	finding of no significant impact
ft	foot
gal	gallon
gpd	gallons per day

ACRONYMS AND ABBREVIATIONS (CONTINUED)

GTE HTCo	GTE Hawaiian Telephone Company
ha	hectare
HAR	Hawai‘i Administrative Rules
HELCO	Hawai‘i Electric Light Company
Hg	mercury
HRS	Hawai‘i Revised Statutes
in	inch
IR	infrared
IRTF	NASA Infrared Telescope Facility
JAC	Joint Astronomy Center
JACH	Joint Astronomy Center Hilo
JB	junction box
JCMT	James Clerk Maxwell Telescope
JPL	Jet Propulsion Laboratory
kl	kiloliter
km	kilometer
klpd	kiloliters per day
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
l	liter
lb	pound
LBT	Large Binocular Telescope, Arizona
LEPC	Local Emergency Planning Committee
m	meter
mgd	milligrams per day
mi	mile
MKOOC	Mauna Kea Observatories Outreach Committee
MKSR	Mauna Kea Science Reserve
MKSS	Mauna Kea Support Services
mm	millimeter
MOA	Memorandum of Agreement
mph	miles per hour
MSDS	Material Safety Data Sheet
mt	metric ton
N	newton

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NGLT	Next Generation Large Telescope
NHPA	National Historic Preservation Act
No(s)	number
NO_x	nitrogen oxide
NPDES	National Pollution Discharge Elimination System
NRAO	National Radio Astronomy Observatory
NRHP	National Register of Historic Places
NSF	National Science Foundation
OEQC	Office of Environmental Quality Control (State of Hawai‘i)
OMKM	Office of Mauna Kea Management
OSHA	Occupational Safety and Health Administration
OSS	NASA’s Office of Space Science
Pan-STARRS	Panoramic Survey Telescope & Rapid Response System
ppm	parts per million
PTA	Pōhakuloa Training Area
RQ	reportable quantity
RWD	Report of Waste Discharge
RWQCB	Regional Water Quality Control Board
SAAQS	State Ambient Air Quality Standards
SAO	Smithsonian Astrophysical Observatory
SCAB	South Coast Air Basin
SCAQMD	South Coast Air Quality Management District
SCBA	self-contained breathing apparatus
SDAB	San Diego Air Basin
SDCAPCD	San Diego County Air Pollution Control District
SERC	State Emergency Response Commission
SHPD	State Historic Preservation Division
SHPO	State Historic Preservation Officer
SMA	Smithsonian Submillimeter Array
SMT	Submillimeter Telescope
SOP	standard operating plan
SO_x	sulfur oxide
SWRCB	State Water Resources Control Board
TMT	Thirty Meter Telescope
TOTS	Temporary Optical Test Site

ACRONYMS AND ABBREVIATIONS (CONTINUED)

TPQ	Threshold Planning Quantity
UBC	Uniform Building Code
UH	University of Hawai‘i
UH IfA	University of Hawai‘i Institute for Astronomy
UKIRT	United Kingdom Infrared Telescope
U.S.C.	U.S. Code
USDA	U.S. Department of Agriculture
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VATT	Vatican Advanced Technology Telescope
VIS	Visitor Information Station
VLBA	Very Long Baseline Array
VLTI	Very Large Telescope Interferometer, Chile
VOC	volatile organic compound
VQO	Visual Quality Objective
WDR	Waste Discharge Requirement

USEFUL TERMS

aa — geological term meaning rough clinker lava; from Hawaiian word *ʻaʻā.*

adaptive optics — an optical system that corrects for blurring or other optical effects of the atmosphere so that a ground-based telescope can form sharp images.

ʻahinahina — silversword (a high-altitude native plant).

ahu — cairn, altar, sacred platform, mound.

ahupuaʻa — land division, usually extending from the uplands to the sea.

Akua — god, goddess; spiritual or human being of immense power.

aliʻi — chief, chiefess, priest, priestess; member of elite class.

angular resolution — the level of detail that you can see; measure of how sharp the view is of the object being observed.

anticyclone — high pressure zone.

ʻāpana — district (traditional vertical land section); land parcel; piece.

astrometric signature — the wobble of a star due to the gravitational influence of an unseen planetary companion.

astrometry — the precise measurement of the motions and positions of celestial bodies.

ʻaumakua —personal or family gods; deified ancestral spirits who might take several shapes.

autecology — branch of ecology that focuses on individual organisms (or species) and how those organisms influence or are influenced by their environment.

cinder cone — steep conical hill of volcanic fragments that accumulates around and downwind from a vent. Can range in size from tens to hundreds of meters tall.

entomologist — a scientist who studies insects.

Ghyben-Herzberg lens (fresh water) — a body of fresh water buoyantly overlying marine water.

Hāloa — first Hawaiian man.

handhole — a re-enterable container, usually buried to at least grade level or lower, used as a pull box for buried cable.

hāpuʻu — Hawaiian tree fern (*Cibotium chamissoi*).

he mau wai koloa — ponds inhabited by the native Hawaiian duck.

heiau —place of worship; temple; shrine.

interferometry —combining light from two or more telescopes to produce greater angular resolution than each telescope separately could produce.

USEFUL TERMS (CONTINUED)

kahuna — priest, expert, religious practitioner.

kaluakāko'i — cave or pit for making adzes.

kapu — taboo, prohibited, forbidden; sacred.

kauhale — house compound; groups of buildings, including eating houses, sleeping houses, and cookhouses.

Keck Interferometric Array — any combination of the four Outrigger Telescopes with one or both of the Keck Telescopes.

Keck-Keck Interferometer — Keck I and Keck II used together as an interferometer (without the Outrigger Telescopes).

Keck Telescope —the Keck I or Keck II Telescope.

kahakai — ocean edge (7th horizontal land unit).

kuahiwi — very sacred summit lands.

kualono — near-summit lands (2nd horizontal land unit).

kula — upland grassy plains (used as cultural resource—everyday purposes) (6th horizontal land unit).

kea — white, clear, pale (Kea, abbreviation for Wakea: great sky god).

keanakāko'i — cave or pit for making adzes.

koa — large native forest tree (wood used for canoe hulls) (*Acacia koa*).

kuahu — altar.

kuahu manu — altar for bird catchers.

Kūkahau'ula — pink-tinted snow god (traditional name for highest peak at summit; also called Pu'u Wēkiu or Mauna Kea peak).

kupuna —grandparent, ancestor, relative, or close friend of the grandparent's generation; grandaunt; granduncle (Kūpuna — plural of Kupuna).

light-year — the distance that light would travel in a vacuum in one year, 9.46 trillion kilometers or 5.8 trillion miles, used in measuring astronomical distances.

Līlīnoe — goddess of mists

māmane —native tree common in upland forests (*Sophora chrysophylla*).

marae — Polynesian temple with uprights.

mauna —mountain, mountainous region, mountainous.

USEFUL TERMS (CONTINUED)

mele — chant, song.

mo'olelo — story, tale, legend, myth.

moku o loko — district (traditional large vertical land section and political division).

naio — a type of native tree common in upland forests (*Myoporum sandwicense*).

nēnē — native Hawaiian goose.

'ōhi'a —native tree common in upland forests (*Metrosideros* spp.)

'okana — district (traditional vertical land section and political division comprising several *ahupua'a*).

'ō'ō — digging stick or spade.

'ō'ō — type of honeycreeper (extinct native bird once hunted for colorful feathers).

'ōpihi — limpet (meat eaten; shells used as scraping/peeling tool) (*Cellana* spp.).

Outrigger Array — any combination of the Outrigger Telescopes alone.

Outrigger Telescope — any of six 1.8-m (6-ft) telescopes.

Pae — high chief in the time of 'Umi (16^{th} century); an exceptional fisherman.

Papa — earth mother.

Pele — volcano goddess.

permafrost — perennially frozen ground occurring wherever the temperature remains below 0° C (32° F) for several years, whether the ground is consolidated by ice or not and regardless of the rock and soil particle composition of the earth.

pili — a grass.

pixel — smallest unit of an image on a television or computer screen.

po'ina nalu — ocean edge (7^{th} horizontal land unit).

Poli'ahu — goddess of the snows of Mauna Kea.

proto-stellar disk — disk of dust and gas in space believed to be an early stage of star formation.

pulu — silky fiber collected from *hāpu'u* (tree fern) for pillow and mattress stuffing.

pu'u — (singular and plural) any kind of protuberance, from a pimple to a hill: hill, peak, cone, hump, mound, bulge, heap, pile, portion, bulk, mass, quantity, clot, bunch, knob.

Pu'u Hau'oki — frosty peak (westernmost summit cone).

USEFUL TERMS (CONTINUED)

seeing —amount of degradation of an optical image by the Earth's atmosphere. Good seeing implies minimal degradation.

stellar debris disk — cloud of gas or other material remaining after a star is formed.

synoptic scale — pertaining to regional scales.

taro — aroid with edible leaves and corm (underground stem) (*Colocasia esculenta*); main Hawaiian staple food (*kalo*).

tephra — a rock composed of fragmented volcanic material ejected in eruptions.

ʻuaʻu —dark-rumped petrel, an endangered sea bird considered by some an *ʻaumakua* (personal god).

vadose zone —the zone immediately below the land surface and above the water table.

vent — the opening at the Earth's surface through which volcanic materials (lava, tephra, and gases) erupt. Vents can be at a volcano's summit or on its slopes.

Waiau — one of Poliʻahu's companions (Lake Waiau (also known as Poliʻahu's pond) and Puʻu Waiau are named for her).

wao — environmental and cultural zone.

wao maʻu kele — (below ke kualono) large area of koa, *ʻohiʻa*, lobelia, and mamane (3rd horizontal land unit).

wao akua — varied forest land (4th horizontal land unit).

wao kanaka — lowest forested area (used as cultural resource—everyday purposes) (5th horizontal land unit).

wēkiu — tip, top, topmost, summit.

CONVERSION FACTORS

Linear

1 centimeter (cm) = 0.3937 inch (in)	1 in = 2.54 cm
1 cm = 0.0328 foot (ft)	1 ft = 30.48 cm
1 meter (m) = 3.2808 ft	1 ft = 0.3048 m
1 m = 0.0006 mile (mi)	1 mi = 1609.3440 m
1 kilometer (km) = 0.6214 mi	1 mi = 1.6093 km
1 km = 0.53996 nautical mile (nmi)	1 nmi = 1.8520 km
	1 mi = 0.87 nmi
	1 nmi = 1.15 mi

Area

1 square centimeter (cm^2) = 0.1550 square in (in^2)	1 in^2 = 6.4516 cm^2
1 square meter (m^2) = 10.7639 square ft (ft^2)	1 ft^2 = 0.09290 m^2
1 square kilometer (km^2) = 0.3861 square mi (mi^2)	1 mi^2 = 2.5900 km^2
1 hectare (ha) = 2.4710 acres (ac)	1 ac = 0.4047 ha
1 hectare (ha) = 10,000 square m (m^2)	1 ft^2 = 0.000022957 ac

Volume

1 cubic cm (cm^3) = 0.0610 cubic in (in^3)	1 in^3 = 16.3871 cm^3
1 cubic m (m^3) = 35.3147 cubic ft (ft^3)	1 ft^3 = 0.0283 m^3
1 cubic m (m^3) = 1.308 cubic yards (yd^3)	1 yd^3 = 0.76455 m^3
1 liter (l) = 1.0567 quarts (qt)	1 qt = 0.9463264 l
1 l = 0.2642 gallon (gal)	1 gal = 3.7845 l
1 kiloliter (kl) = 264.2 gal	1 gal = 0.0038 kl

Weight

1 gram (g) = 0.0353 ounce (oz)	1 oz = 28.3495 g
1 kilogram (kg) = 2.2046 pounds (lb)	1 lb = 0.4536 kg
1 metric ton (mt) = 1.1023 tons	1 ton = 0.9072 metric ton

Energy

1 joule = 0.0009 British thermal unit (BTU)	1 BTU = 1054.18 joules
1 joule = 0.2392 gram-calorie (g-cal)	1 g-cal = 4.1819 joules

Pressure

1 newton/square meter (N/m^2) = 0.0208 pound/square foot (psf)	1 psf = 48 N/m^2

Force

1 newton (N) = 0.2248 pound-force (lbf)	1 lbf = 4.4478 N

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